Study of formation of high aspect GaAs structures based on the method of focused ion beams

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The possibilities of nanolithography technologies aren't able to match modern requirements for processing and forming a surface of a predetermined type of relief with high resolution. At the current moment, there are a number of technologies with a combination of photo- or electron beam lithography and liquid etching, which don't allow obtaining the required result. This fact is supported by the dependence of size of structures formed by the methods of photo- or electron beam lithography, on the wavelength of exposure. In this connection, traditional methods of lithography aren't able to overcome the barrier of topological size in 50 nm [1-4].

One of the solutions to this problem is the application of method of focused ion beams with subsequent plasma chemical etching. Thanks to this methods combination, it is possible to select such selective parameters, which allow for precise formation of structures and profiling of the surfaces of these structures in accordance with specified characteristics over a wide range.

The experiment method. Experimental studies were performed on plates of intrinsic GaAs with a chemically purified and polished surface. After improving the geometric characteristics, the plates were subjected to processing by the method of focused ion beams. Built-in functions of Nova NanoLab 600 software, the surface layer was modified according to a pre-prepared template. The main parameters of the formation were the ion beam current I = 1 pA, the accelerating voltage U = 30 keV. The number of passes varied from 50 to 120. During this treatment, Ga+ ions were implanted into the surface of the GaAs plate, which resulted in the formation of a near-surface layer of the amorphous state, which was later used as a masking one[5-8].

Plasma chemical etching was carried out in a chlorine-containing medium. The chlorine-containing gas was BCl3 with varied flow rate of N_{BCl3} from 5 to 15 cm^3/min, the Ar gas was used as the transport gas with flow velocity N_{Ar} - 100 cm^3/min. The values of using powers of resistively and inductively coupled plasma are, respectively, W_{RIE} = 10 V and W_{ICP} = 200 V. The etching time ranged from 1 to 3 minutes.

Subsequent investigations of surfaces topology of obtained structures were carried out by scanning electron microscopy.

As a result of the experimental session, dependencies of the flow rate of the chlorine-containing gas on the deviation angle from the vertical for different crystallographic axes was obtained.

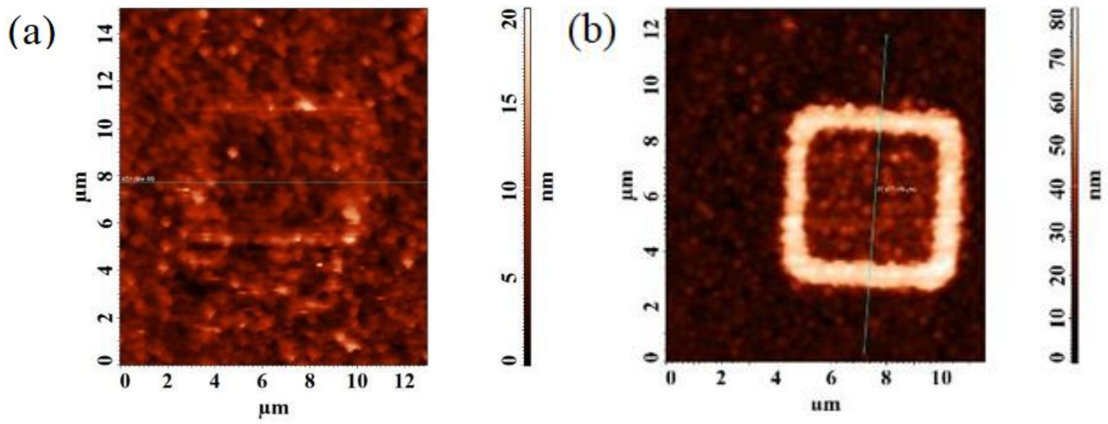

Figure 1. The structures etched by plasma chemical etching after electronic processing at 100 passes, 30 seconds of exposure in plasma (a) before plasma chemical etching, (b) after plasma chemical etching

According to these dependencies, it was concluded that when the flow of chlorine-containing gas is reduced, an increase in the verticality of walls is observed, regardless of the direction of crystallographic axes. Obtained parameters of the etching process can be integrated into different technologies of obtaining structures with nanoscale lateral characteristics. With the increase of flow, a flat wall is formed, which allows, in the presence of various layers in the structure, to bring electrical contact to different layers of the given structure

During the implementation of experimental studies, a technique for nanosized profiling of GaAs structures by a combination of local anodic oxidation and plasma chemical etching was developed and implemented.

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1. V.S. Klimin et al., *J. Phys.: Conf. Ser.* **917**, 092005 (2017).
2. R.V. Tominov et al., *IOP Conf. Ser.: Mater. Sci. Eng.* **256,** 012023 (2017).
3. V.S. Klimin et al., *J. Phys.: Conf. Ser.* **741,** 012178 (2016).
4. N.N. Rudyk et al., *J. Phys.: Conf. Ser.* **917,** 082008 (2017).
5. R.V. Tominov et al., *J. Phys.: Conf. Ser.* **917,** 032023 (2017).
6. V.S. Klimin et al., *Proc. of SPIE* **10224**, 102241Z-1 (2016).
7. M.V. Ilina et al., *Proc. of SPIE* **10224,** 102240U-1 (2016).
8. V.S. Klimin et al., *J. Phys.: Conf. Ser.* **917,** 092023 (2017).